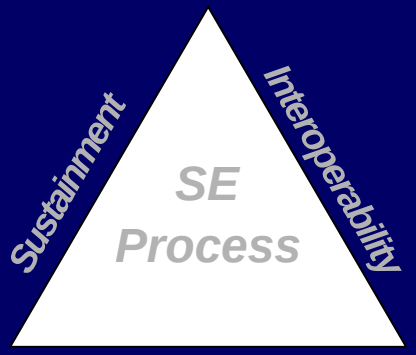
Certified Naval Battle Groups



Predator SRAW Performance Analysis & Product Improvement (PAPI) Process

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NDIA System Engineering Conference Oct 21-24 2002

PREDATOR SRAW
Performance Analysis & Product Improvement (PAPI) Process

Agenda

- PAPI Process Overview
- Predator SRAW System Overview
- PAPI Process Utilization Example

What is the PAPI Process?

Methodology that utilizes suite of analytical tools to establish baseline (BL) performance & assess whether proposed changes possess sufficient merit to warrant further consideration.

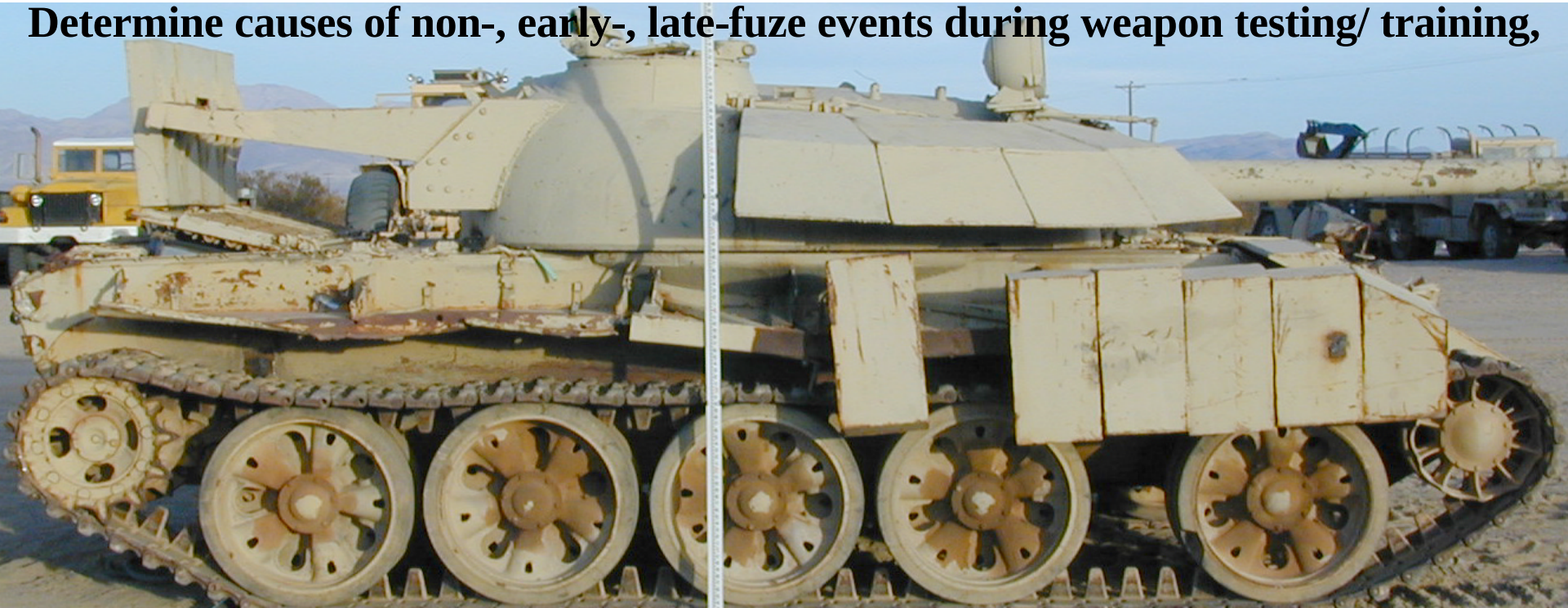
Why is PAPI Process Needed?

- **Provide expert advise to Marine Corps concerning weapon utility**

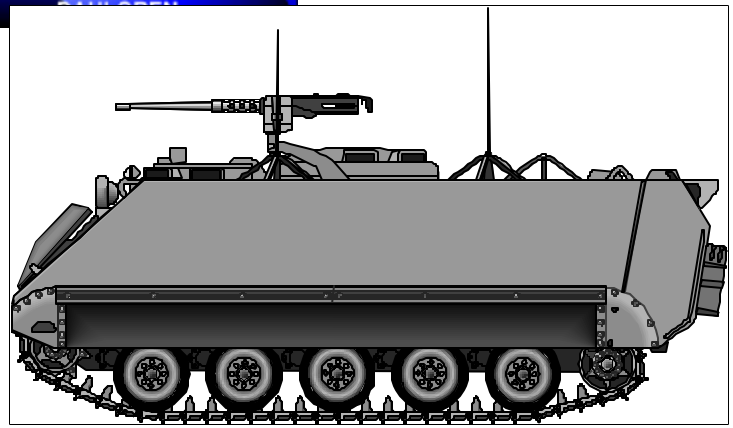
- **Assess impacts of proposed changes to BL during lifecycle:**
  - **desired cost reduction**
  - **tactics & requirements evolution**
  - **filling void left by retirement of other weapon systems**
  - **foreign military sales**
  - **technology insertions**

Evaluate Suitability of Surrogate Targets For Testing/Training

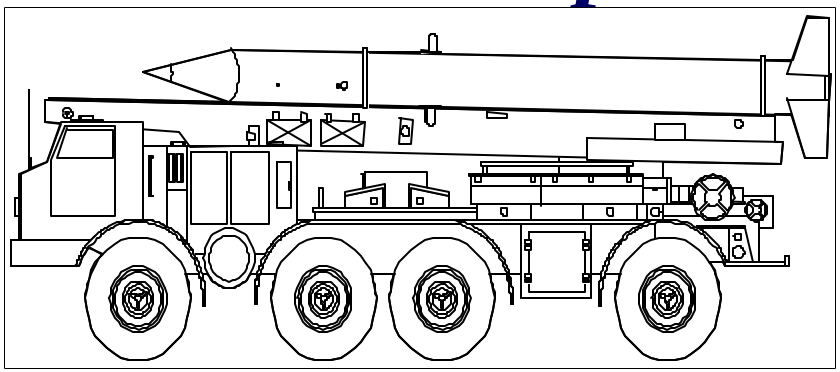
Determine causes of non-, early-, late-fuze events during weapon testing/ training,



Explore Performance Envelop



Current Aluminum-Hulled Objective Threats



Targets Outside of Current Threshold & Objective Set

to place order – http://www.niistali.ru/ english//products/military/emps.htm

Future Threats Composed of Non-ferrous Materials

Supporting Analytical Tools

- NSWC 6-DOF Model – predicts missile flight dispersion
- Magnetic Field Mapper – measures magnetic field surrounding threat targets
- TDD Simulator – determines target detection performance
- SRAW Analyzer – auto-analyzes system performance
- PILOT – measures system-level impacts of changes to baseline

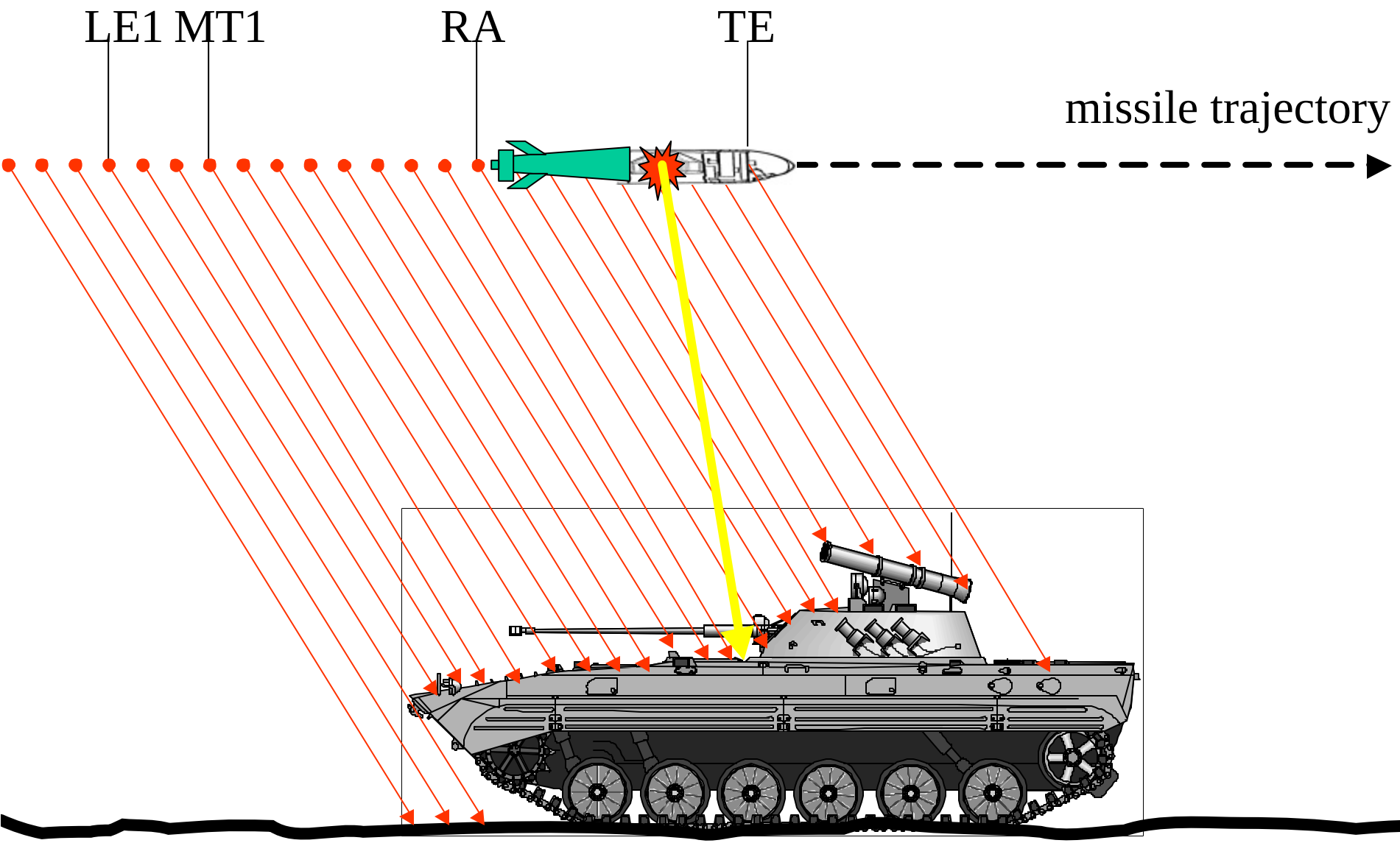
Predator SRAW Overview

- Shoulder-launched Fire & Forget Missile
- ~ 22 pounds, ~34” long
- Targets
  - ➔Threshold = Main Battle Tanks
  - ➔Objective = Other Armored Vehicles
- Range of 17 - 600m (stationary) & 17 - 200m (moving @ speeds ≤ 24km/hr)
- Required $P_{hit} > 0.5$
- Fire-from-enclosure Capability
- Fixed-reticle Optical Sight

Predator SRAW Overview (continued)

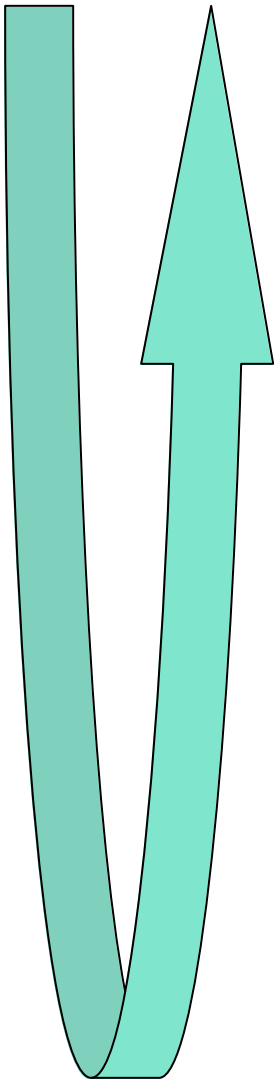
- Missile Inertially Guided to Fly Over Target Based on Gunner's Aim Point
- Target Detection Device Senses Target's Presence & Initiates Warhead
- Explosively Formed Penetrator (EFP) Punctures Top-surface Creating Spall & Overpressure Inside Target
  - ➔Effective Against Reactive Armor

Representative Engagement



PAPI Process Steps

- **Compose Decision Statement**
- **Determine Analysis Factors**
- **Exercise Flight & Target Detection Simulators**
- **Analyze Engagement Results**
- **Add Results to BL Performance Library**
- **Employ PILOT to assess system tradeoffs**



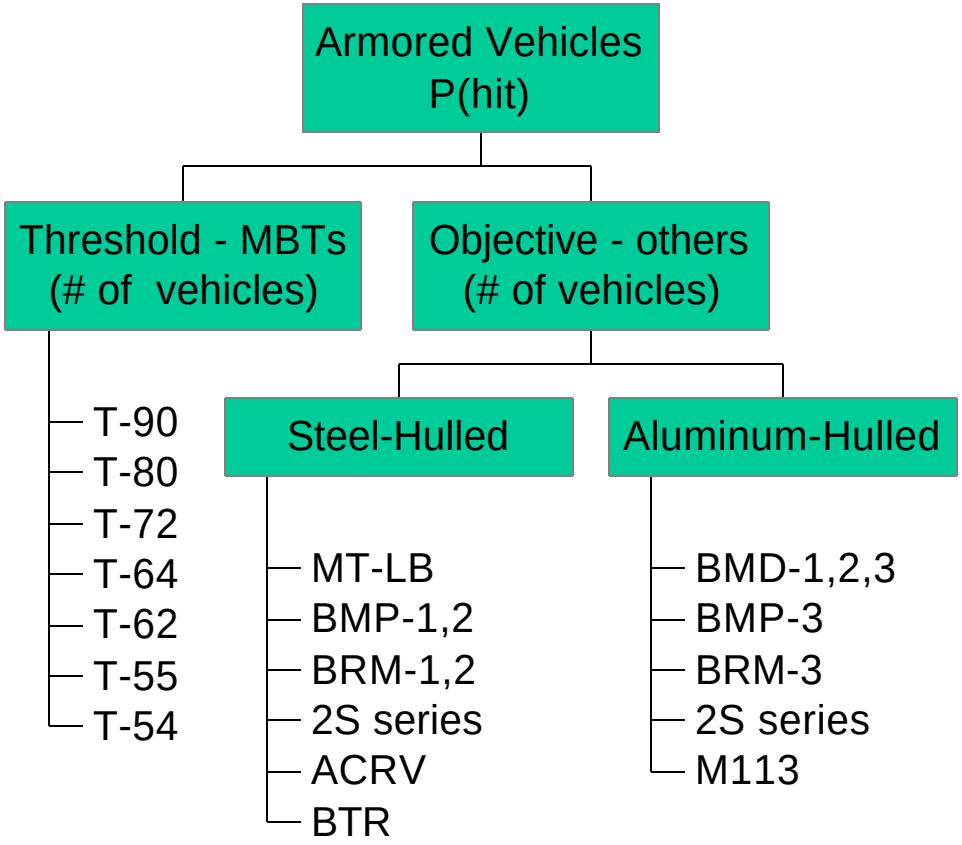
Example Decision Statement

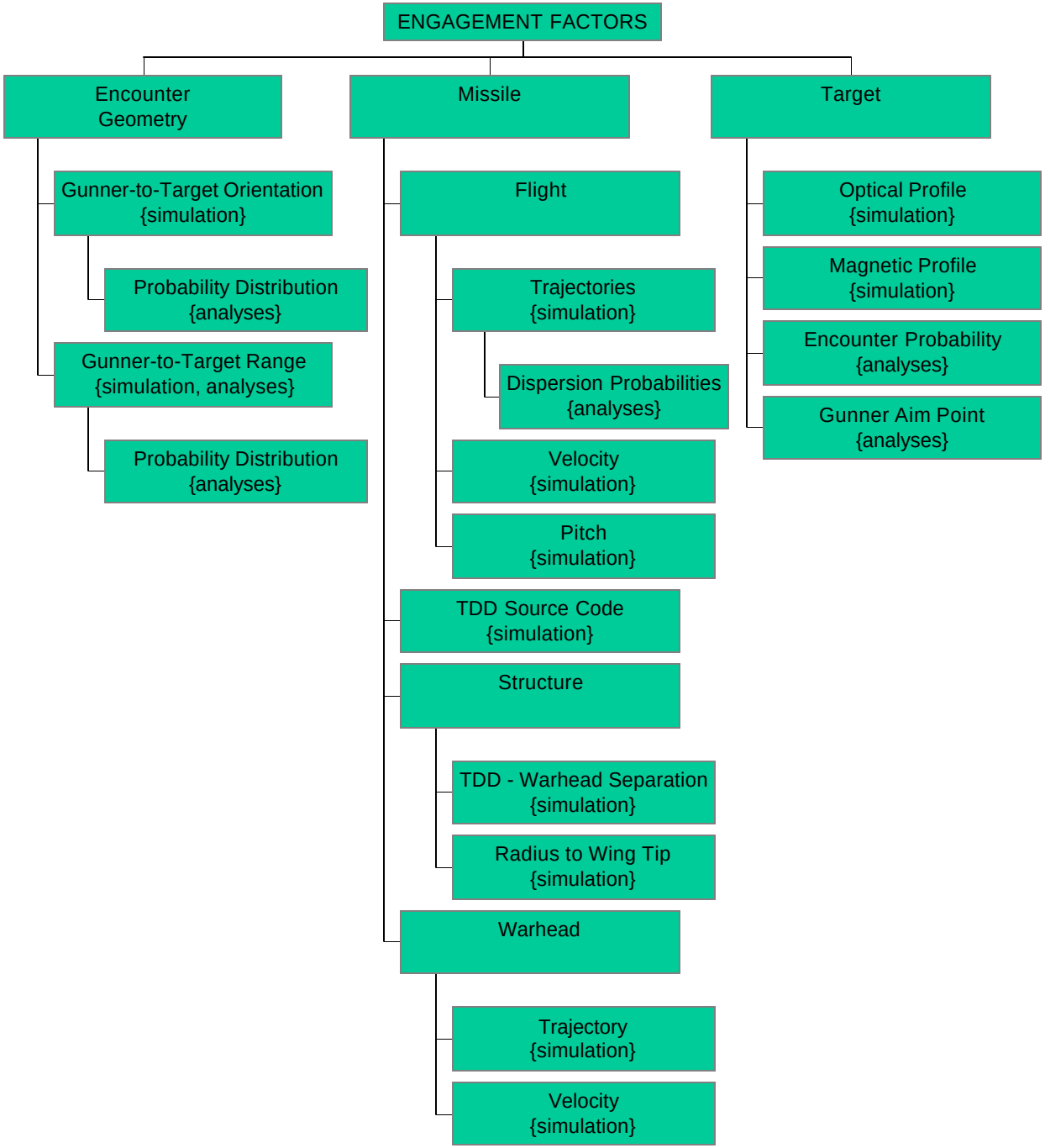
- Is SRAW effective against aluminum-hulled armored vehicles?
  - ➔P_{hit} is system-level measure of effectiveness (MOE).

- If not, is there a non-material PI option to ensure effectiveness while preserving performance against threshold and steel-hulled objective threats.
  - ➔$P_{hit} > 0.5$ for both threshold & objective threat classes

Determine Analysis Factors

- Determine threat populations of interest



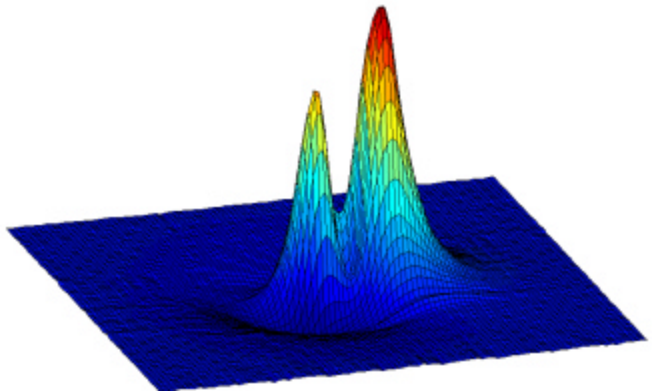

ENGAGEMENT FACTORS
Encounter Geometry
Missile
Target
Gunner-to-Target Orientation {simulation}
Probability Distribution {analyses}
Gunner-to-Target Range {simulation, analyses}
Probability Distribution {analyses}
Flight
Trajectories {simulation}
Dispersion Probabilities {analyses}
Velocity {simulation}
Pitch {simulation}
TDD Source Code {simulation}
Structure
TDD - Warhead Separation {simulation}
Radius to Wing Tip {simulation}
Warhead
Trajectory {simulation}
Velocity {simulation}
Optical Profile {simulation}
Magnetic Profile {simulation}
Encounter Probability {analyses}
Gunner Aim Point {analyses}

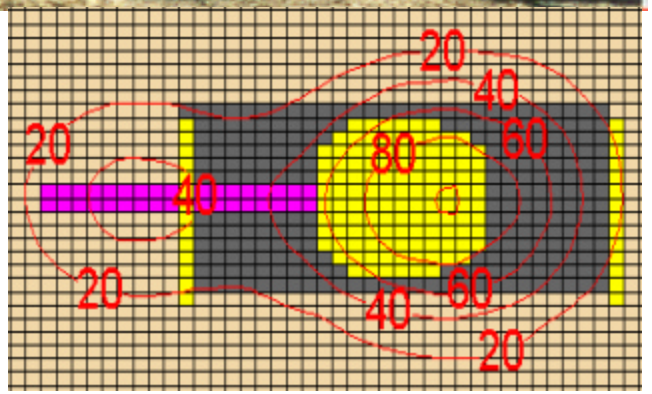
Exercise SRAW Flight & TDD Simulators

- 6-DOF Flight Model used to predict missile flight dispersion, pitch & velocity as a function of range

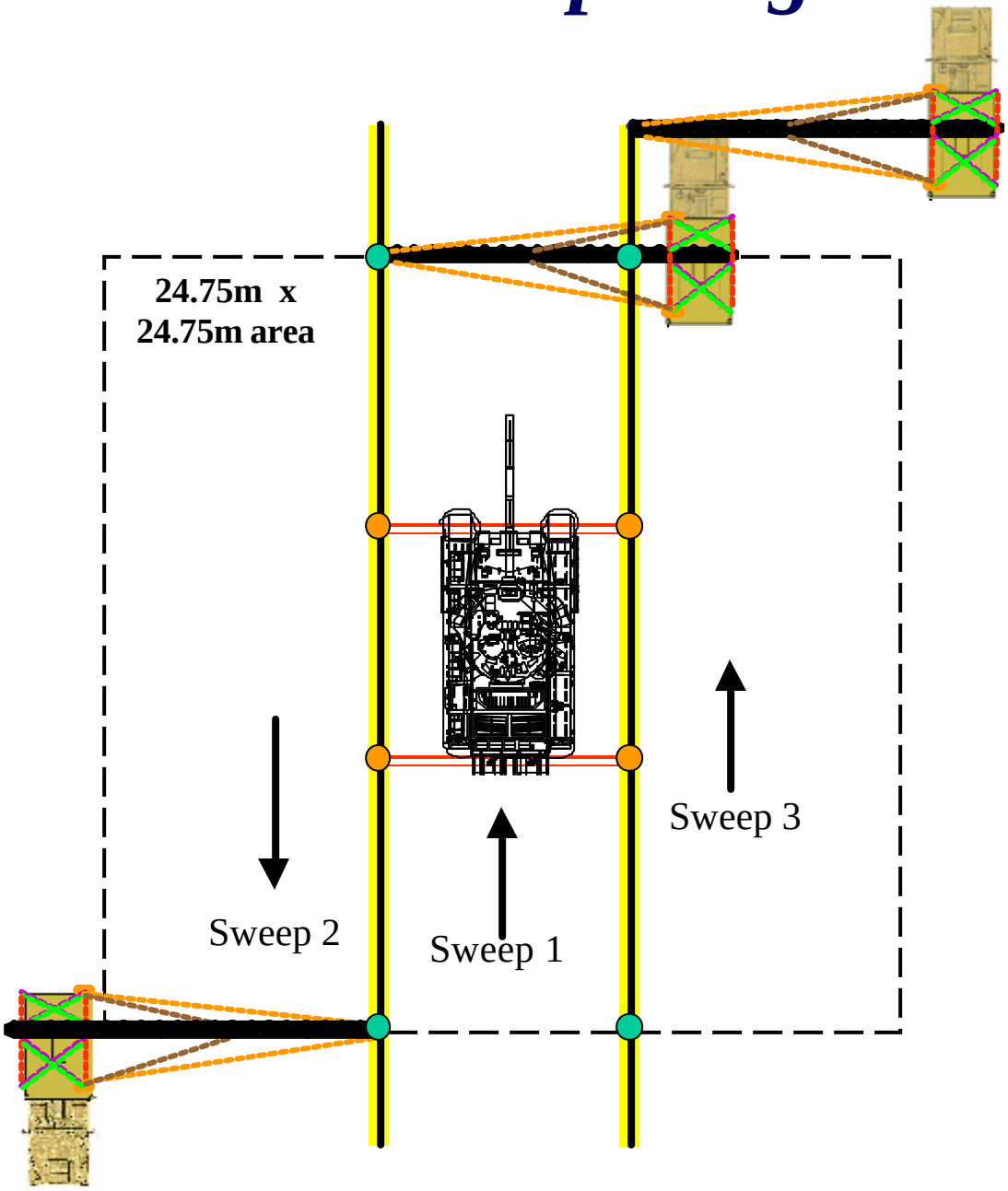
- TDD simulator requires magnetic & optical profiles for the target of interest
  - ➔If on-hand, then simulate engagements
  - ➔If not, measure target field & generate optical profiles

Magnetic Field Mapper (Magmapper)



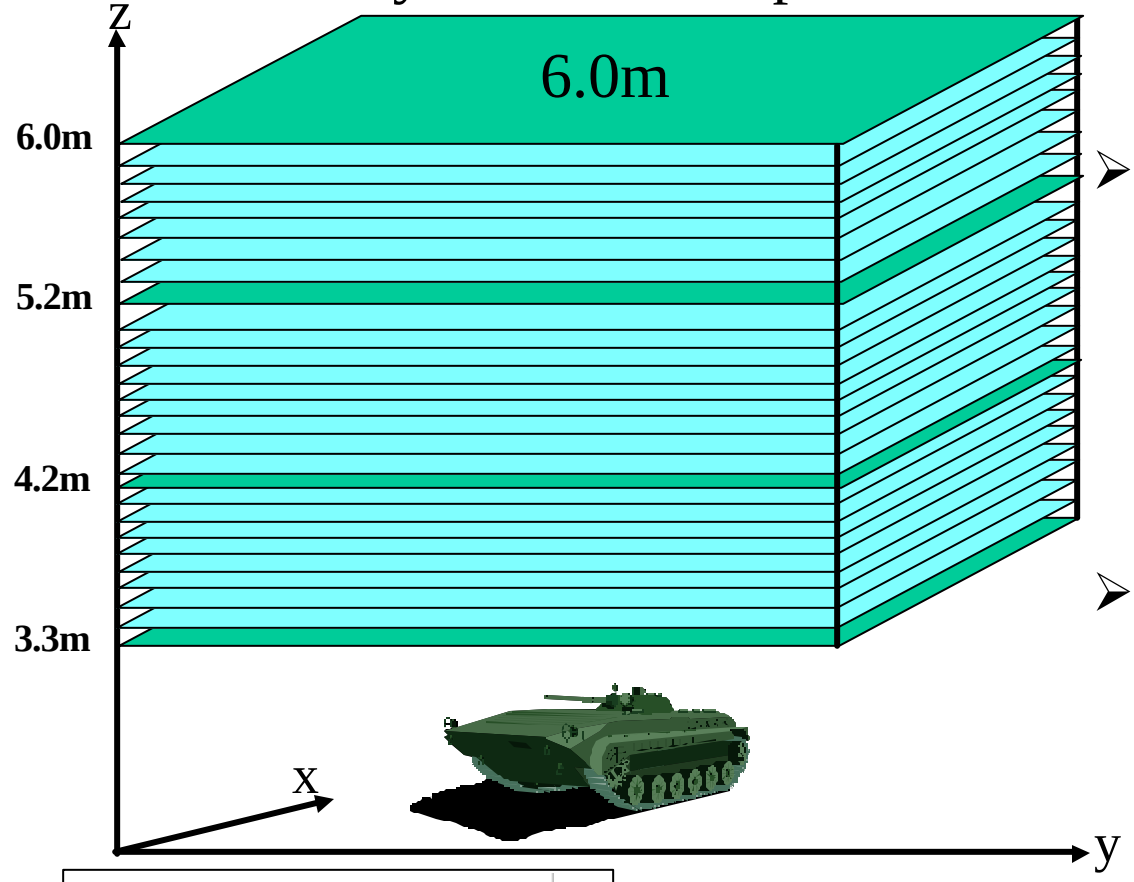


Sweep Progression

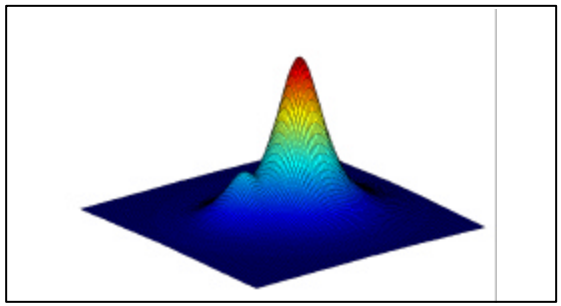


Magnetic Field Cube

- Created by Surface Interpolations Among Measured Field Maps



- **27 Field Cubes Generated:**
  - **ACRVs = type 1V14 & 1V15**
  - **APCs = BTR-60, MT-LB**
  - **MBTs = M60, type 69, T-54, T-55, T-72**
- **Utilization**
  - **Predator Performance Library**
  - **NGIC, SIGINT Division**
  - **ARL, Sensors Integration**



28 field maps compose a cube

Corpheyeus SW Application Used to Generate Optical Profiles

Viewpoint Model

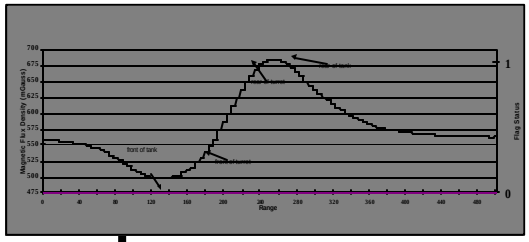
CG2 Model

Simulation Structure

PC

Missile vel., pitch, dia.
Warhead vel., trajectory

PVWave

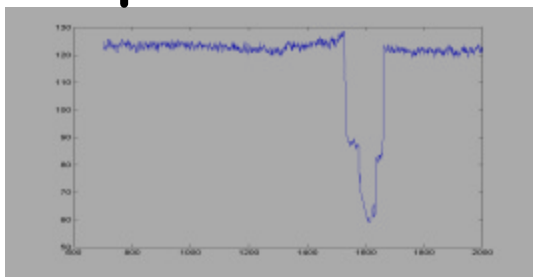


Measured Magnetic Profiles

Spatially Registered Engagement Array Pairs

TDD Source Code

Virtual Optical Profiles



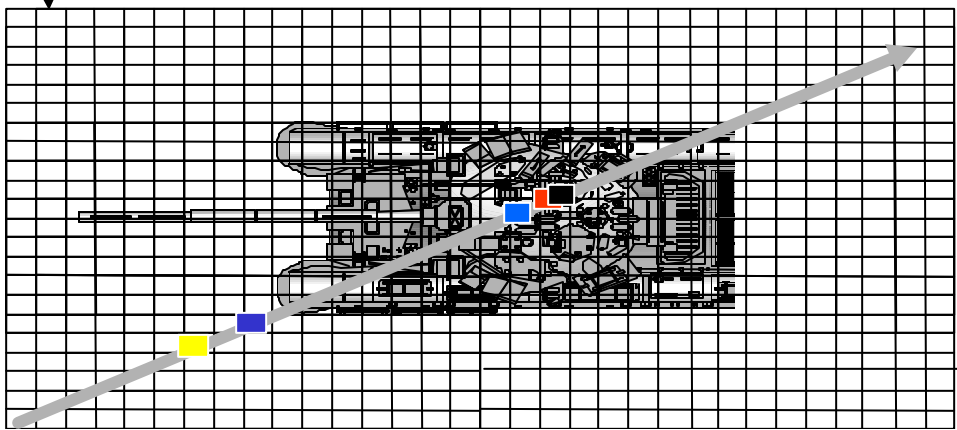
	T-72 Engagement Table
1 **2** **3** . . . **7696**	Engagement Parameters & TDD Responses Recorded For Thousands of Engagements

TDD Logic Flag Trail
(for single or set of engagements)

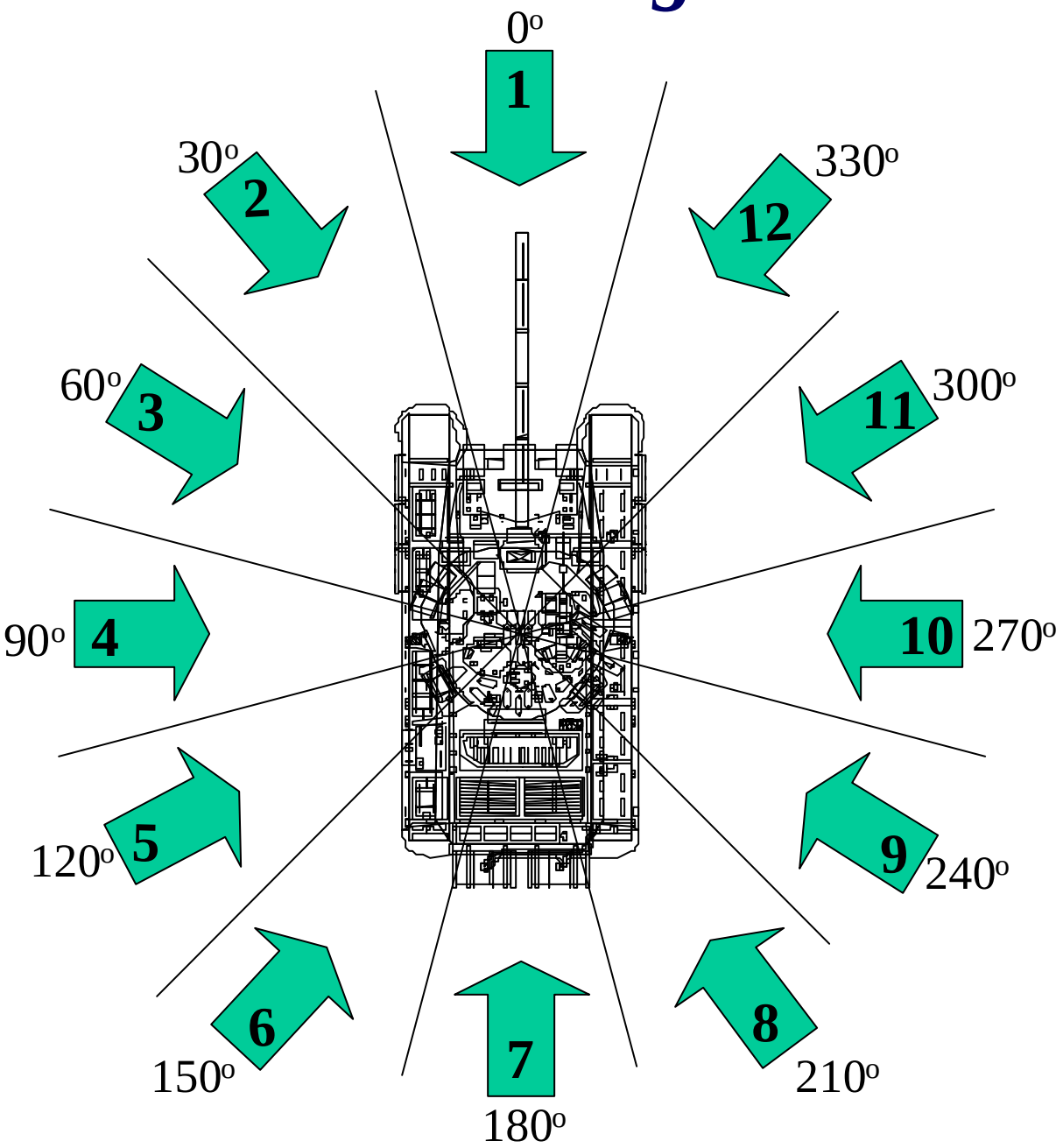
Target Indicators { **LE1**, **MT1**, **TE**

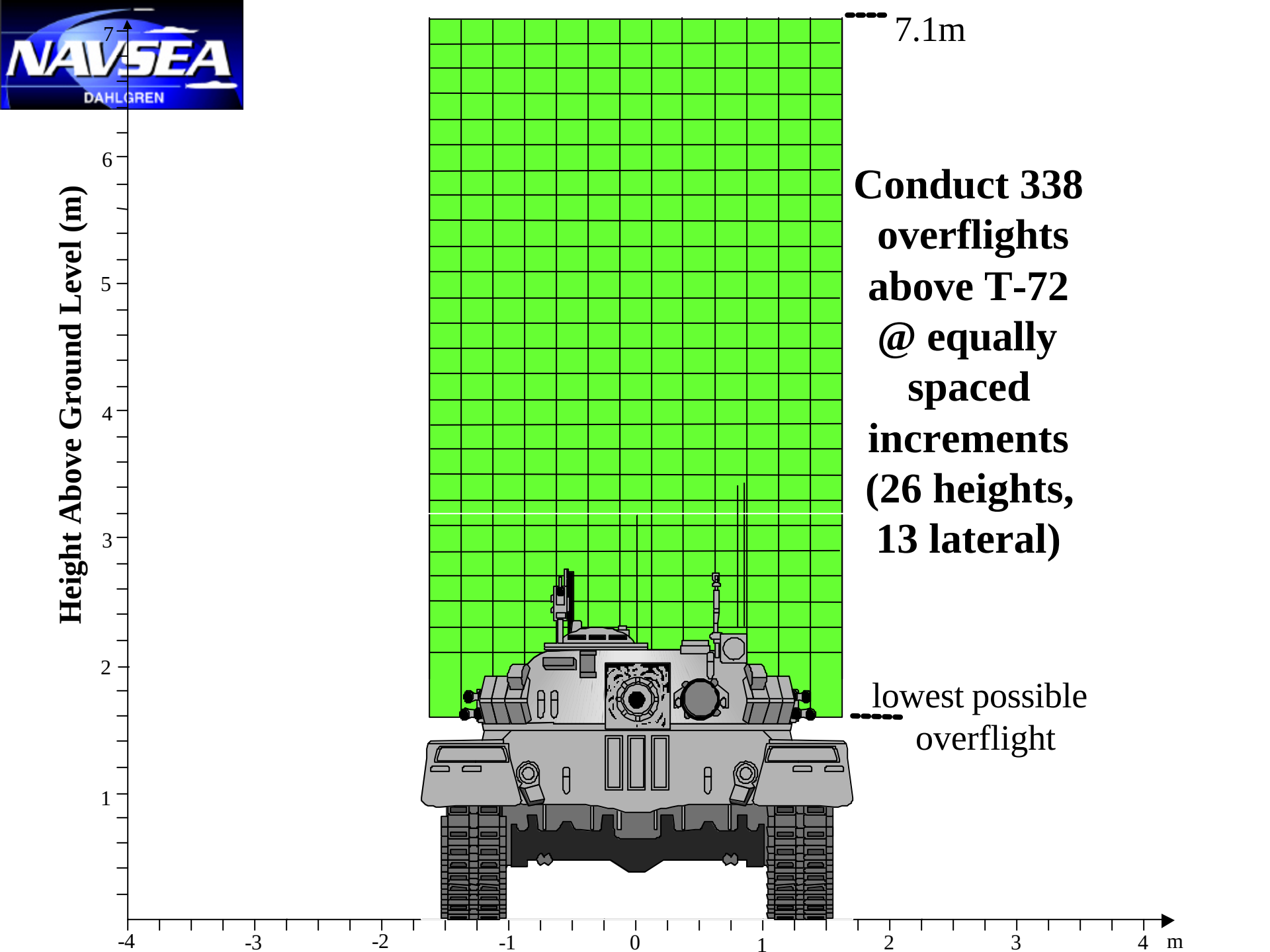
Fuze Point **WF1**

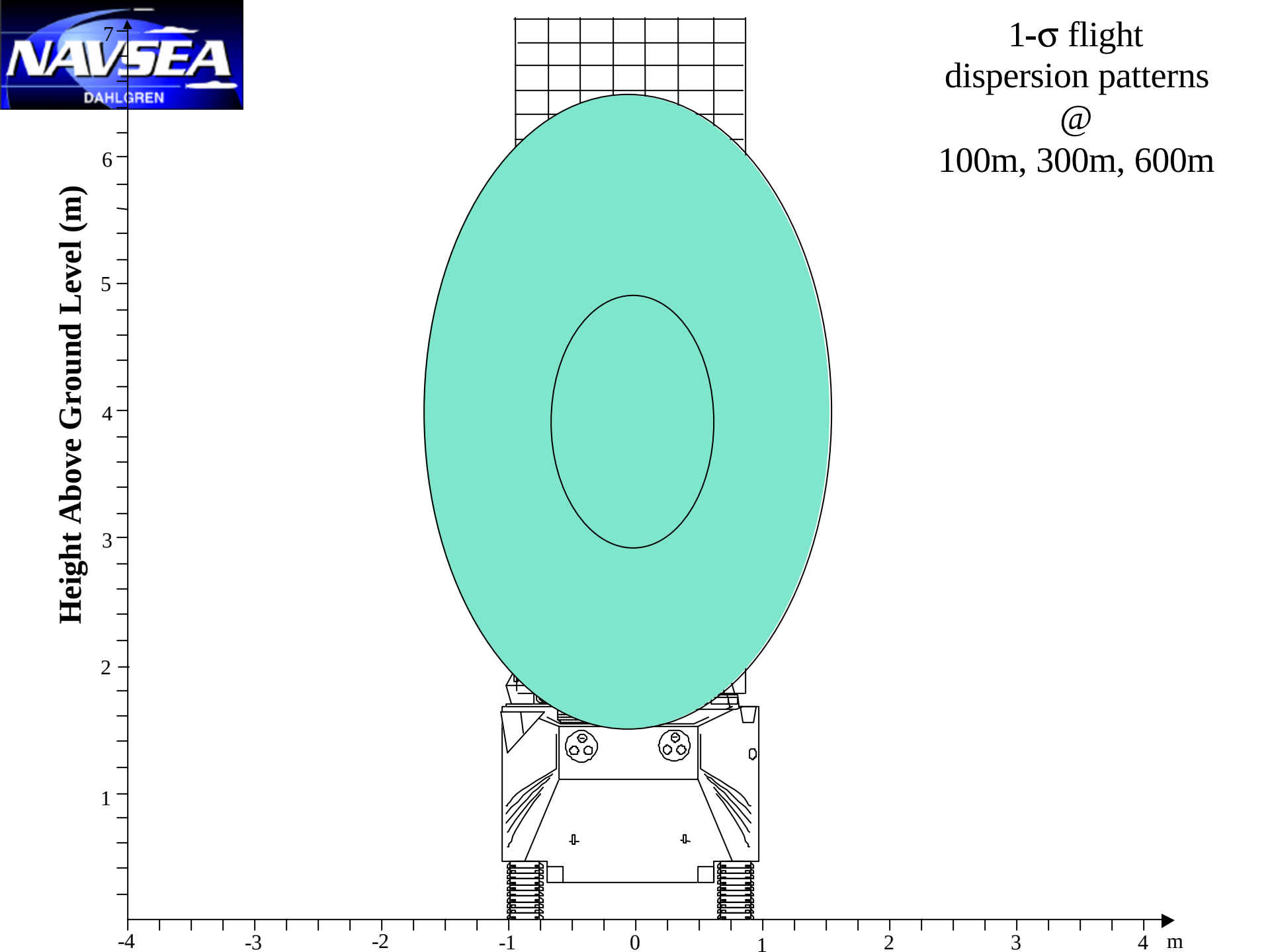
Hit Point **Hit**



Gunner-to-Target Orientations




NAVSEA
DAHLGREN
Height Above Ground Level (m)
7
6
5
4
3
2
1
-4
-3
-2
-1
0
1
2
3
4
m
7.1m
Conduct 338 overflights above T-72 @ equally spaced increments (26 heights, 13 lateral)
lowest possible overflight


NAVSEA
DAHLGREN
1-σ flight
dispersion patterns
@
100m, 300m, 600m
Height Above Ground Level (m)
7
6
5
4
3
2
1
-4
-3
-2
-1
0
1
2
3
4
m

NAVSEA DAHLGREN

Simulation

	Engagement Table
1 2 3 . . .	Engagement Parameters & TDD Responses Recorded For Each Engagement

Analyses

1 reference information
2 dispersion plots (display)
1 dispersion data (processing)
10 bar charts (display)
12 scatter plots (display)
72 witness screens (display)
1 centerline calc. (processing)
1 scorecard (processing)
1 data entry (processing)

Flight Dispersion over Range
P(GTO)
P(target encounter)
Aim Point
Target Dimensions
Missile Clearance

Excel Workbook composed of 101 worksheets

Analyzer Summary

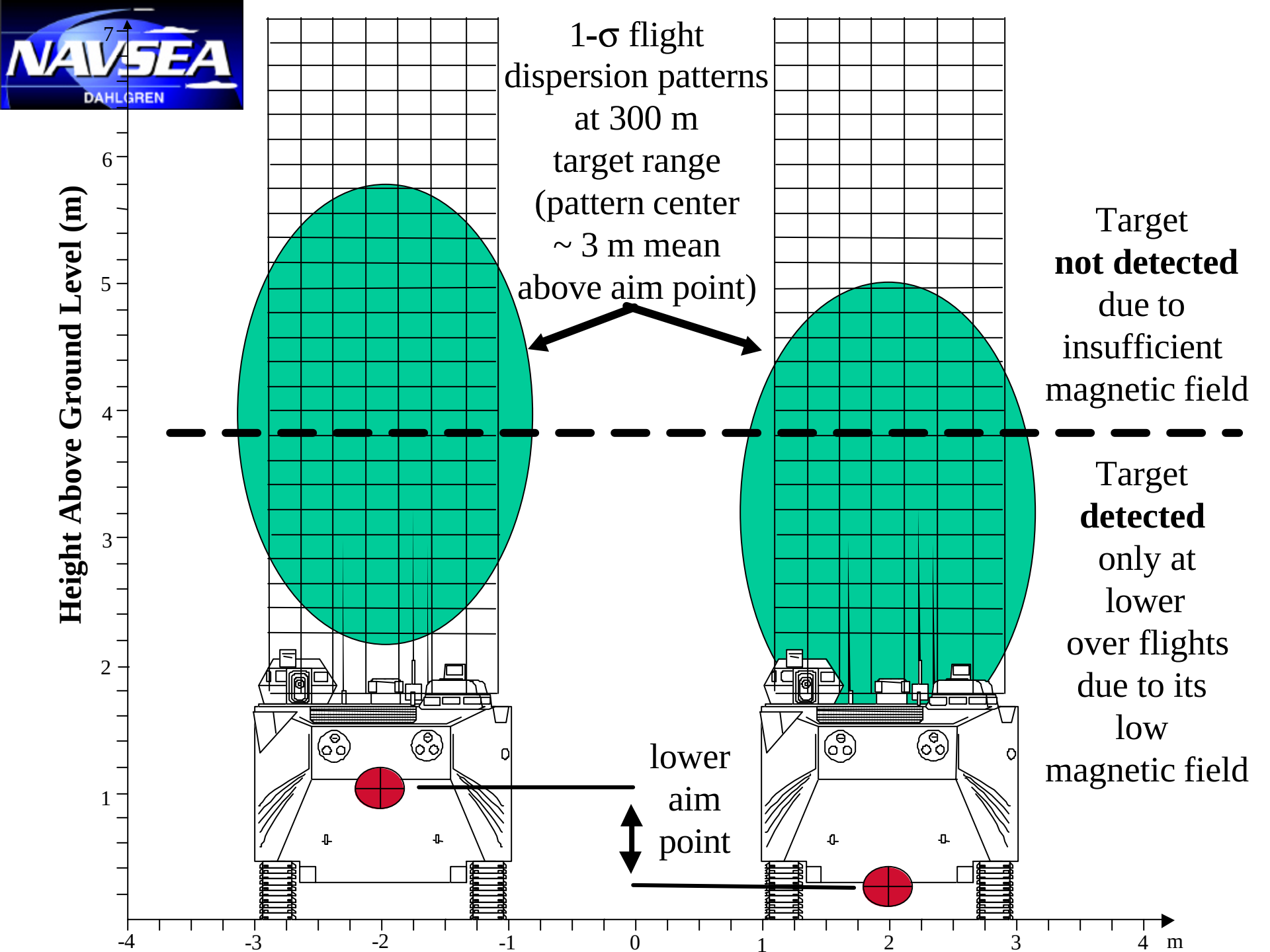
- P_{hit} reported as system measure of effectiveness
  - ➔further characterized by centerline statistics & hit point plots
- P_{fd} & P_{d} reported as subsystem measures of performance
- P_{miss} elements identify subsystem entities & interactions responsible for inadequate performance
- Remaining 98 bar charts, witness screens, & graphs provide path to assess & trace performance issues back to the target characteristics

Performance Summary Against Aluminum-hull Threat

- If $P_{hit} > 0.5$, then performance is acceptable

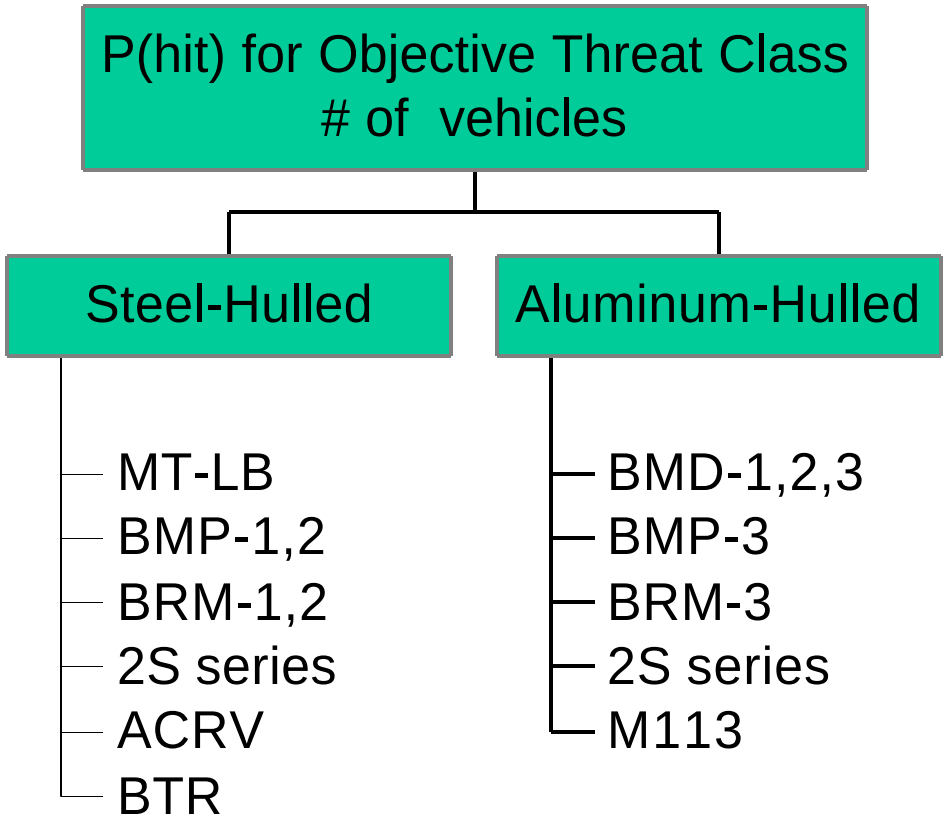
- If not, then assess non-material options:
  - ➔ #1. lower aim point for objective threats
  - ➔ #2. lower missile climb above aim point
  - ➔ #3. modify TDD algorithms

- Choose #1 since it does not impact MBT performance
  - ➔ assess impact to performance against steel-hulled threats


NAVSEA
DAHLGREN
1-σ flight dispersion patterns at 300 m target range (pattern center ~ 3 m mean above aim point)
Target **not detected** due to insufficient magnetic field
Target **detected** only at lower over flights due to its low magnetic field
lower aim point
Height Above Ground Level (m)
7
6
5
4
3
2
1
-4
-3
-2
-1
0
1
2
3
4
m

Assess Performance Impact

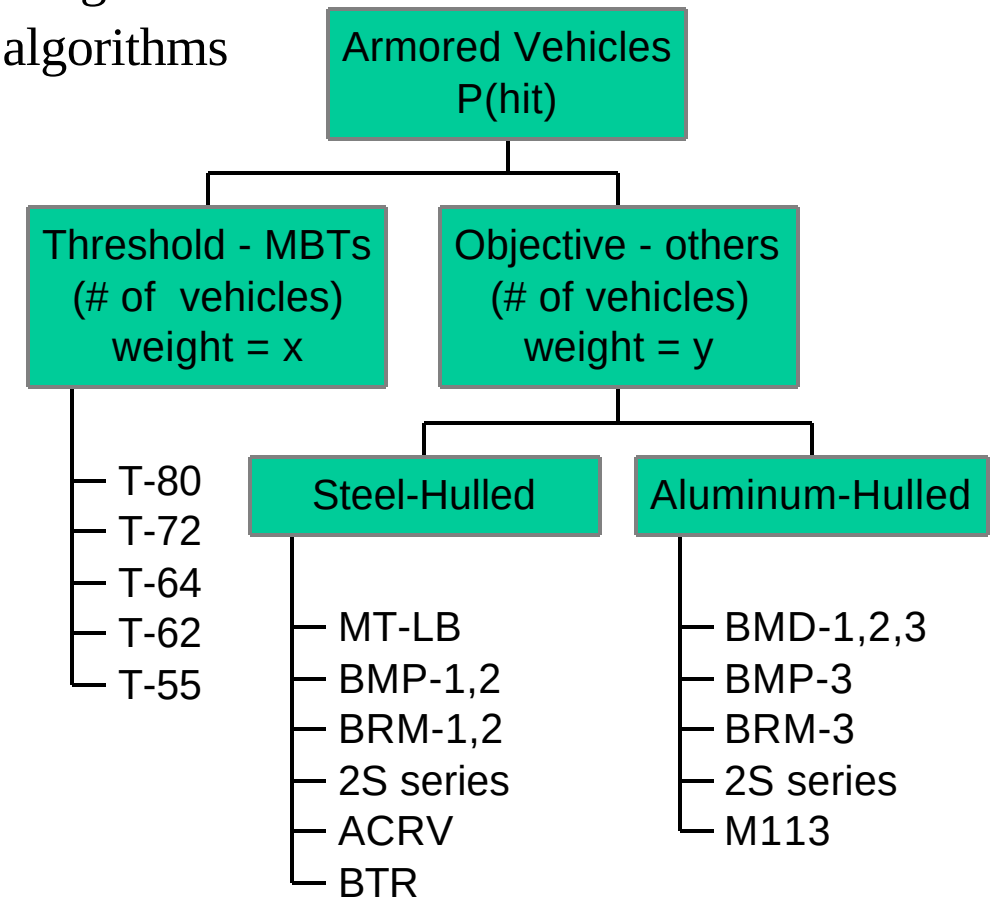
- Determine P_{hit} for original & new aim point
  - ➔ use population % to weight P_{hit} of individual threats



- ✓ **Choose higher P_{hit} even if aluminum-hull $P_{hit} < 0.5$**

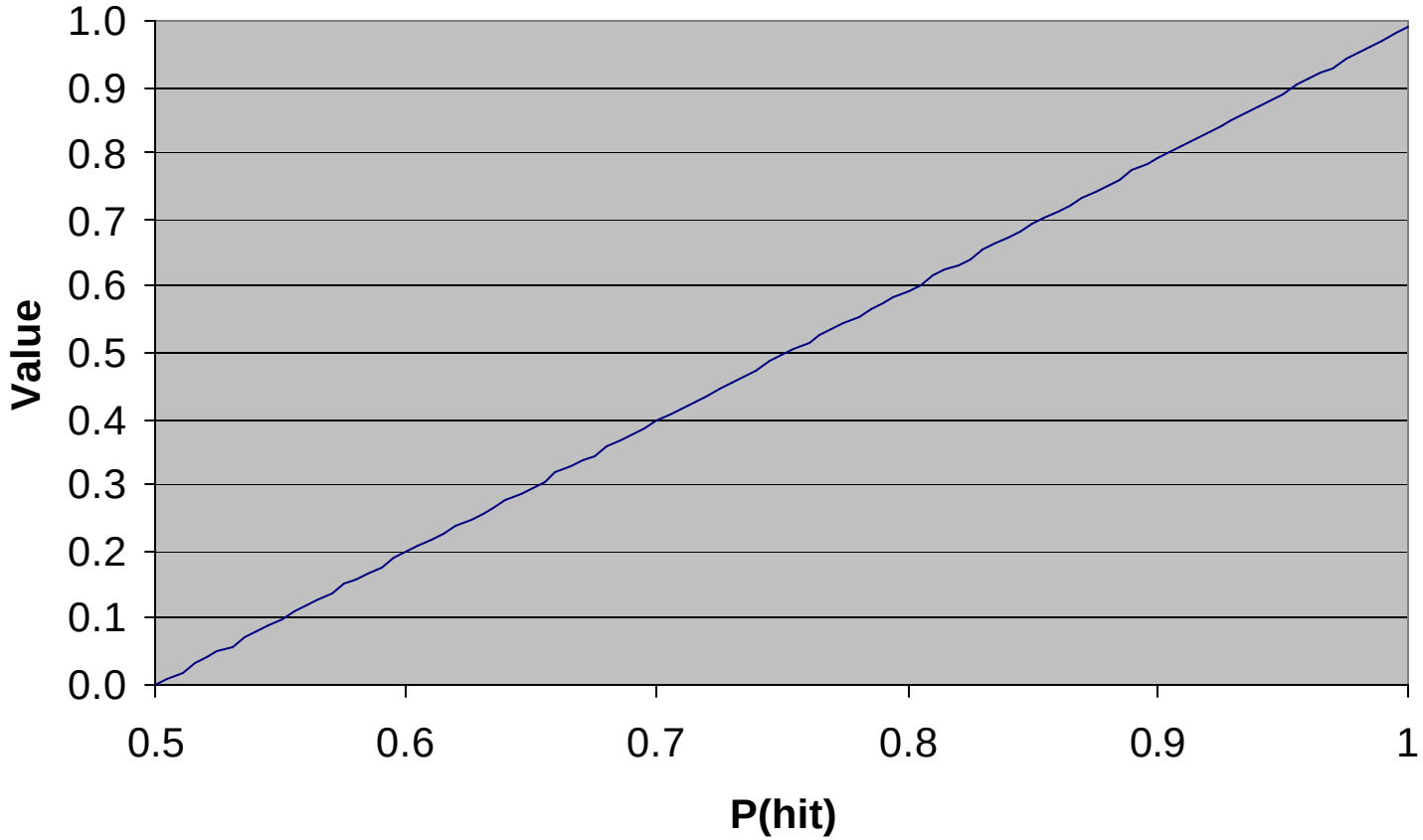
If Aim Point Change Inadequate…

- Other options may impact performance against MBTs
  - ➔ #2 lower missile overflight height
  - ➔ #3 modify target detection algorithms



- How do you trade-off performance? – Employ PILOT
  - ➔need Marine Corps to establish relative importance via weights

Establish Value Function & Score Options

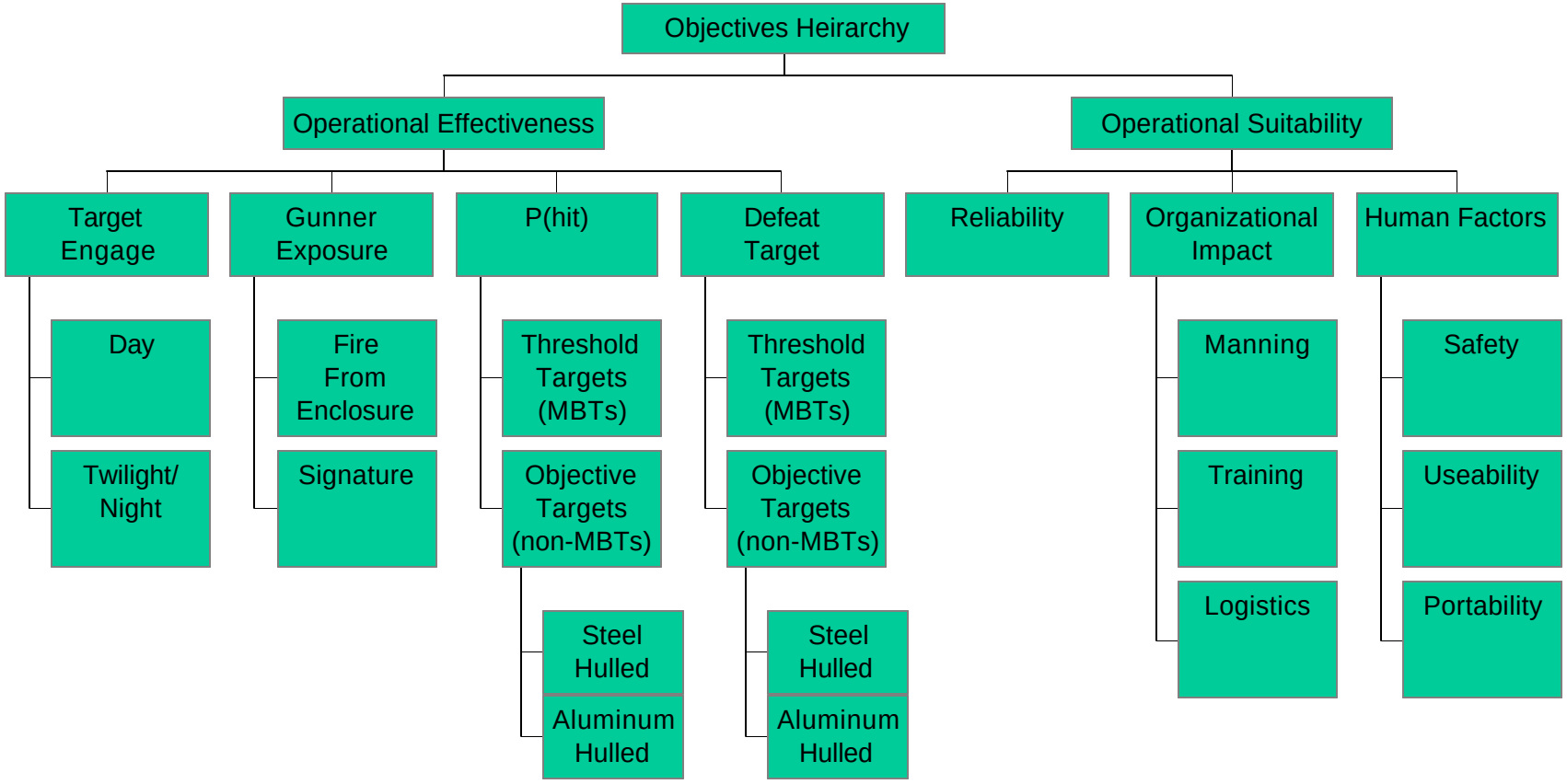


- Compare baseline against all options using:

Weighted Value of P_{hit}(MBTs) + Weighted Value of P_{hit} (non-MBTs)

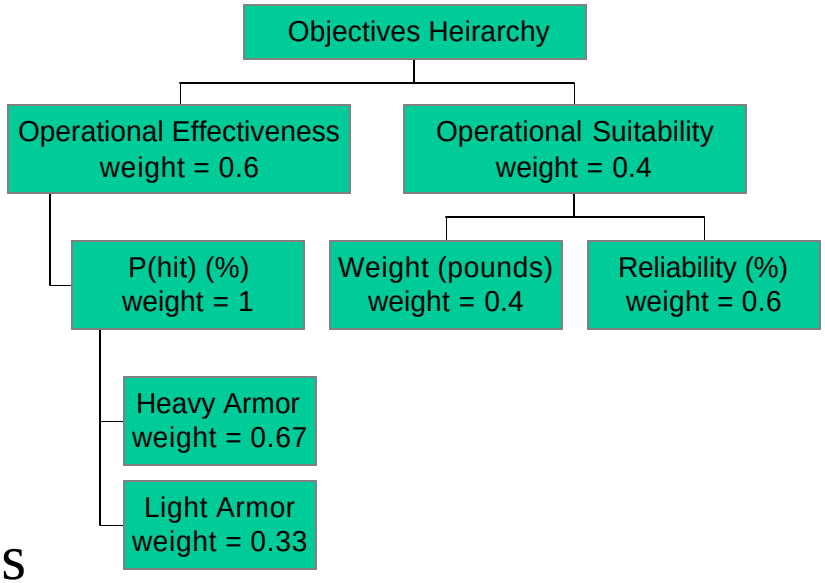
If Non-material Solutions Inadequate

Determine Potential Impacts To BL



Employ Product Improvement Level Objectives Technique

- Conceive applicable objectives hierarchy for proposed product improvement
- Construct value functions
- Collect relevant data/information to score objectives
- Convert measured objectives to values
- Calculate, recompose upwards
- Compare alternatives – IF PI scores higher, iterate to next step



Multi-objective Value Analysis

- Used to decompose a complex problem

- Quantifies classic engineering trade-offs
  - ➔subjective & objective factors addressed
  - ➔all factors converted from their natural scale to a 0-1 scale

- Engages decision-makers so that result gets enacted
  - ➔solicits their values
  - ➔secures their buy-in

- Structured decision process is documented, iterative

PAPI Process Conclusions

- Effective & efficient methodology tool to analyze & visualize performance against threat spectrum:
  - ➔current MBTs & other armored objective threats
  - ➔explore performance envelop against non-objective threats
  - ➔establish baseline to assess product improvements

- Iterative methodology to assess PI against BL based on available & trusted information
  - ➔effort focused on major decision drivers
  - ➔expandable to incorporate new information
  - ➔allows escape at decision points